Mean Reversion of Natural Gas Prices

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Introduction

Managing natural resource projects requires that future costs and revenues be forecasted. Most commodity pricing models are fairly simple, involving a slow, steady increase in base prices while including volatility. When analyzing stock prices, this pattern is commonly referred to as the 'random walk'. Complicating the forecasting process is the fact that many commodities exhibit mean reverting tendencies, where prices may increase or decrease, but tend to revert to a long-term mean. Stock price volatility is measured using the standard deviation of the rate of return of a stock. Commodity price volatility is the same; however, when mean reversion exists, the normal standard deviation will overestimate true volatility. This complicates the pricing of many types of derivatives that are based on commodity prices.

Real options analysis is a tool intended to value management flexibility in future decisions. The mathematical foundation of real options is based on financial options. An example of a real option can be illustrated by an oil firm that continues to lease potential development tracts even though development is not currently economic. Paying for the lease (keeping a real option open) can preserve the future opportunity of developing the tract (exercising the real option).

The Black-Scholes model is used to determine the value of options, and many of the related valuation techniques have clearly stated assumptions including the lognormal distribution of cash flows. Many financial models, including Black-Scholes, are based on the heat transfer equation from physics and engineering, stated as some variation of Equation (1), representing geometric Brownian motion (Hull, 2009).

$$dS = \mu S dt + \sigma S dz \qquad (1)$$

where S is the stock or commodity price
μ is the expected rate of return
t is time
σ is the volatility of the stock or commodity price
dz is a Wiener process

While many stocks and some commodities are lognormally distributed with Brownian motion, most real projects are not.

Mean Reversion

It has been well documented that many commodities exhibit Brownian motion with mean reversion (Dixit & Pindyck, 1994; Schwartz, 1997; Al-Harthy, 2007). Examples include crude oil, gold, copper, and electricity. This mean reverting tendency limits both upside and downside price potentials that would normally be forecasted using volatility alone. It has been pointed out that the Black-Scholes pricing model will overprice options where the underlying asset is actually mean reverting (Spar & Schwebach, 1998). Schwartz (1997) described several models for the stochastic behavior of commodity prices involving mean reversion.

Some commodities, including oil and natural gas, exhibit mean reversion along with Brownian motion. Over time, prices revert to a long term mean price. Particularly high oil prices will, in time, fall back to a long term mean, and particularly low prices will rise over time. Schwartz (1997) presented several models that may be used to describe price movements in the presence of mean reversion. His Model 1, shown in Equation (2), is a one-factor model that assumes the logarithm of the spot commodity price S follows a mean reverting process.

$$dS = \kappa(\mu - \ln S)Sdt + \sigma S dz$$

where κ is the speed of reversion

Method

Historic spot prices of natural gas are analyzed. The U.S. Department of Energy publishes daily and weekly spot prices for natural gas on their website (www.eia.gov). The database begins in 1986 and continues to the present. This database has been studied for several topics:

- To verify that natural gas prices follow a lognormal distribution
- To determine the volatility of natural gas prices
- To determine the mean reversion speed of natural gas prices
- To determine the variables and constants that pertain to the commodity price model

Results

Monthly spot prices are used for the time period of 1986-2013. These prices are shown in Figure 1.

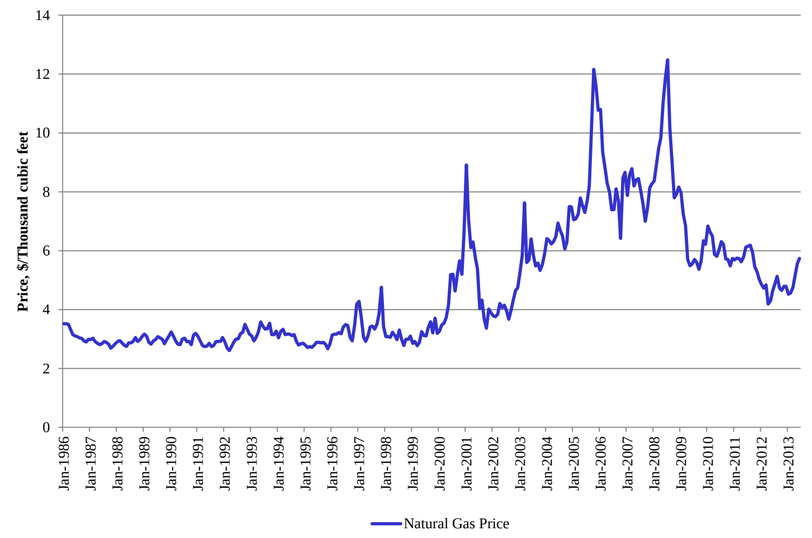

Figure 1. Natural Gas Spot Price, 1986 – 2013.

The monthly spot prices were adjusted for inflation, using the Consumer Price Index to adjust for constant 1986 dollars. These prices are shown in Figure 2, showing that current prices are lower than they were in the late 1980s, on a constant dollar (adjusted for inflation) basis.

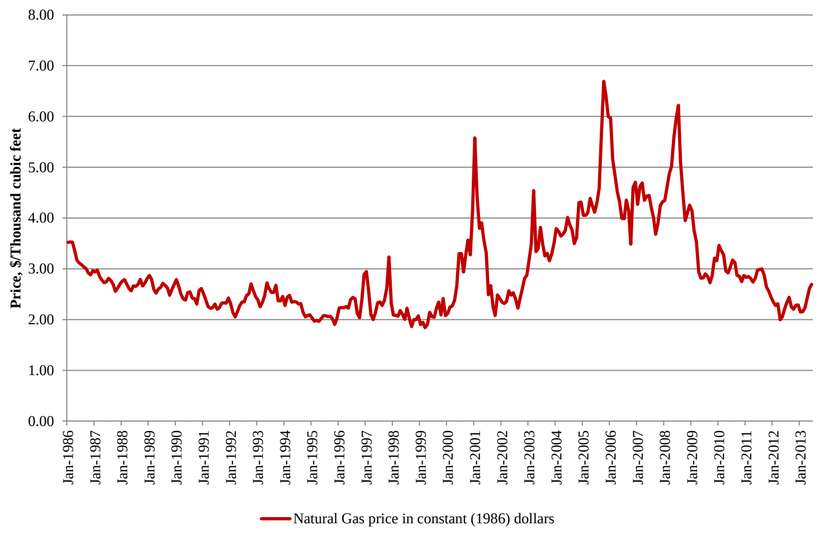

Figure 2. Natural Gas Prices, 1986 – 2013
Adjusted for inflation.

Natural gas prices exhibit mean reversion. The frequency of prices reverting to their long-term mean is not constant, and depends on the time period being studied. The long-term mean and trend also varies depending on the time period. Figure 3 shows the natural gas price run chart along with the best fitting trend line (drawn using Excel for the period 2006 through 2013, with each mean reversion based simply on the graph. Each circle demonstrates a reversion to the mean. Several data points inside the circle show normal variation in prices, and do not demonstrate a new trend. This graph shows 4 mean reversions over a period of 8 years, for a mean reversion speed, κ, of 4/8 years or 0.5 year^{-1}. Note that the long term trend shows that natural gas prices are decreasing. This is due to an increased supply of natural gas, resulting from the implementation of 'fracking'.

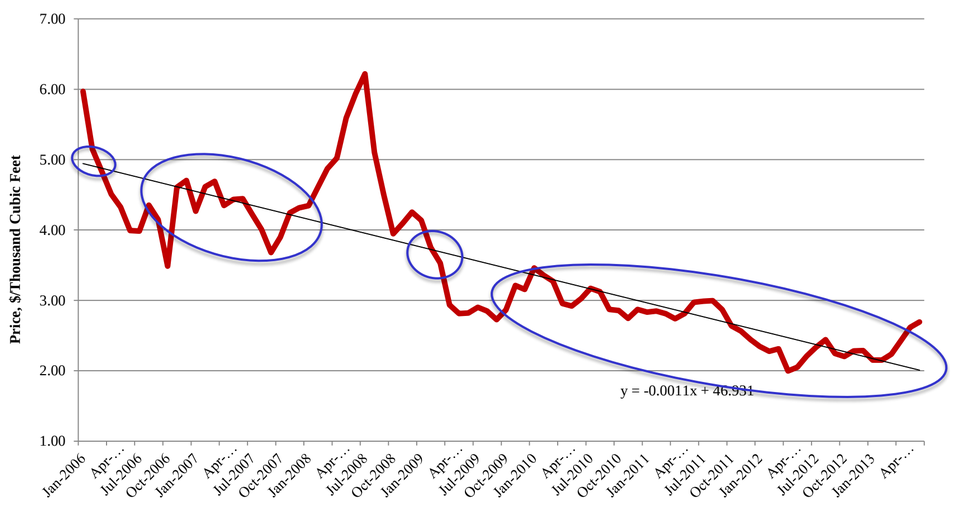

Figure 3. Mean reversion of inflation adjusted natural gas prices, 2006-2013.

Natural gas prices are lognormally distributed, as identified in the literature. A histogram of the long-term database is shown in Figure 4, which verifies the lognormal distribution of the spot prices.

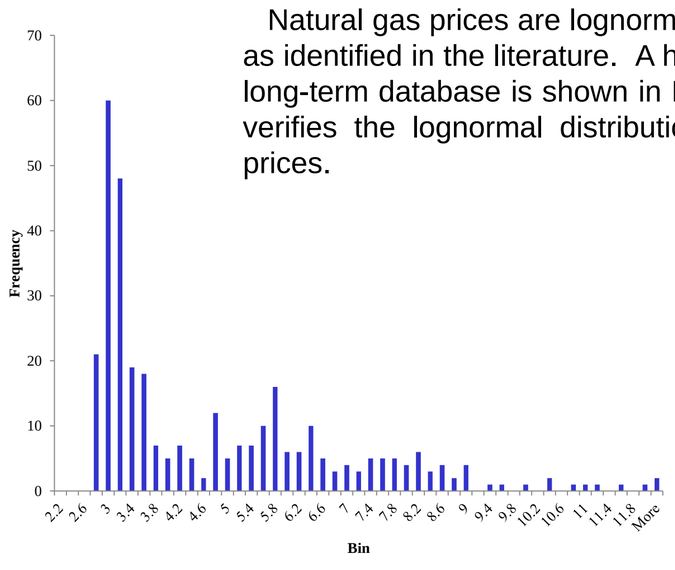

Figure 4. Natural Gas Spot Price Histogram, 1986 – 2013